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Study on the Effect of Pore Fluids on the Liquid Limit of Dispersive and Non Dispersive Clays

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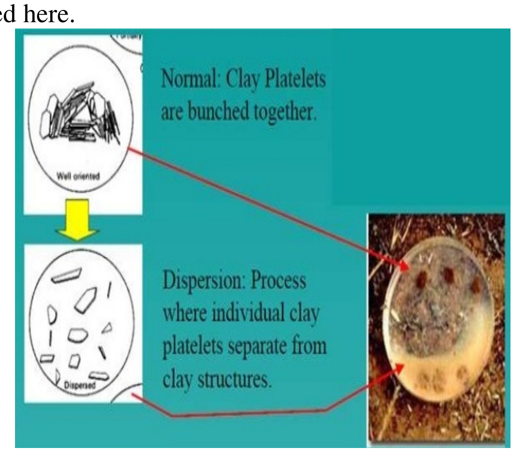
Abstract

The surface and subsurface contamination mainly occurs due to acid rain, disposal of industrial, mining, agricultural wastes and accidental spillage of chemicals on the land. Clays that have high erosion tendency are known as dispersive clays which constitutes of predominance of dissolved sodium in the pore water. They are different from ordinary clays. The dispersive clays are identified by the crumb test. Various environmental factors like overburden pressure, temperature, pore fluid, mineral types, dry density etc. control the properties like shrinkage, swelling, cracking and shear strength. As pore fluid changes properties of soil also changes. This necessitates the study of behaviour of different type of soil in different environmental conditions. The geotechnical behaviour of soils are greatly influenced by the variations in concentrations and properties of pore fluids. The objective of this paper is to determine the influence of various pore fluids on liquid limit of dispersive and non dispersive soils. Various pore fluids used in the study are ammonium chloride and sodium hydroxide which are the common constituents of acid rain and alkali rain. Identification of dispersive soil and effect of pore fluids on liquid limit of dispersive and non dispersive soils were discussed.

Keywords: Contamination, Acid rain, Dispersion, Crumb test, Pore fluids.

Introduction

The surface and subsurface contamination mainly occurs due to land disposal of industrial waste, acid rain and alkali rain. Penetration of chemicals and pore fluids into the soil will affect the properties of soil to great extent. Clays are fine-grained soils that have significant plasticity[1]. Ordinary clays normally constitutes of high content of calcium and magnesium cations whereas dispersive clays have a preponderance of sodium in the pore water[1]. The difference between normal clay and dispersed clay are shown in Figure-1. The crystal structure of clay minerals is the principal factor which determines their physical and chemical properties and their attraction to water. The two forces that act between clay particles affecting dispersion are Van der Waal's attraction forces and the repulsive forces resulting from positively charged cations surrounding each particle. The influence of Van der Waal's forces is only effective over a small area where repulsive forces may extend over a greater distance. The excessive amounts of sodium as opposed to calcium and potassium in dispersive soils have the effect of pushing clay particles away from each other causing the forces of repulsion to act on the clays[2]. The dispersive characteristics of clay soils should be tested in a regular manner while carrying out design studies and for identifying the dispersive soils the laboratory tests like crumb test, double hydrometer test and pinhole test were conducted. Mahabir Dixit and S.L. Gupta conducted a case study on the topic problems in characterization and identification of dispersive soils[2]. Various environmental factors like temperature, pore fluid, mineral types, dry density etc. control the properties like shrinkage, swelling, cracking and shear strength. Michele Calvello studied the effect of aqueous solutions and organic solvents on the strength characteristics and compressibility study of smectitic clays[3]. In Previous studies, Sivapullaih et.al gave a crystal clear cut between dispersive and non dispersive clays[4]. Previous studies showed that pore fluid will affect the various geotechnical properties of soil[1]. As pore fluid changes properties of soil also changes. A study on the effect of various pore fluids, ammonium chloride and sodium hydroxide on the liquid limit of two clayey soils bentonite and metakaolin are presented here.



Source: wikipedia

Figure-1
Difference between normal clay and dispersed clay

Materials and Methods

Materials: Bentonite: Calcium bentonite used in the study was purchased from Ashapura Clay Factory, Trivandrum, Kerala State Properties of calcium bentonite are given in Table-1.

Metakaolin: Metakaolin was obtained from English India Clay Limited, Trivandrum. Metakaolin is calcinated form of kaolin. The properties of metakaolin used for the study is given in Table-1.

Table-1
Properties of Metakaolin and Bentonite

Properties	Values of Metakaolin	Values of Bentonite
Liquid Limit (%)	85	245
Plastic Limit (%)	33	46
Specific Gravity	2.6	2.66
Percentage of clay	65	73
Percentage of silt	34	18
Percentage of sand	1.0	9
Free swell (ml/2g)	3	18
Unconfined compressive Strength (kN/m^2)	87.1	15.4

Pore fluids: The pore fluids used in this study were sodium hydroxide and ammonium chloride which are the common constituents of acid rain and alkali rain. The physical and chemical properties of pore fluids are shown in Table-2.

Methodology: The properties of clay gets modified when they come in contact with different chemicals. The liquid limit variation of dispersive and non dispersive soil were studied. The identification of dispersive clay is done by crumb test. The study was conducted using pore fluids of different molarities or normalities (0.1, 0.2, 0.3, 0.4) varying from lowest to strongest concentrations. Experimental procedures for these tests are explained.

The crumb test (ASTM D 6572-12): One of the tests used for identifying dispersive clays is the crumb test [5]. Place a suitable non porous container that can fully immerse the sample on a horizontal working space which will be relatively free of vibration for the next 6 hour. At 2 minute, 1 hour, 6 hour determine and record the soil dispersion grade in accordance with following criteria:

Grade 1 (Non dispersive): No reaction, the soil may crumble, slake, diffuse and spread out but there is no turbid water created by colloids suspended in water. All particles settle during the first hour.

Grade 2 (Intermediate): Slight reaction, this is the transition grade; A faint bearly visible colloidal suspension causes turbid water near the portions of the soil crumb surface. If the cloud is easily visible assign grade 3.If the cloud is faintly seen is only one small area assign Grade 1

Grade 3 (Dispersive): Moderate reaction, an easily visible cloud of suspended clay colloids is seen around the outside of the soil crumb surface. The cloud may extend up to 10mm away from the soil crumb mass along the bottom of the dish.

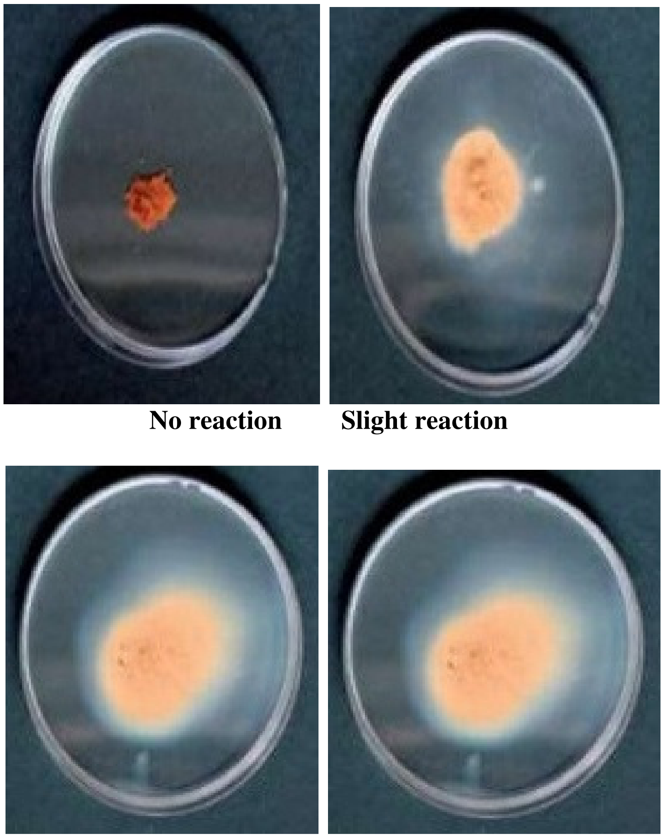
Grade 4 (Highly dispersive): Strong reaction, a dense profuse cloud of suspended clay colloids is seen around the entire bottom of the dish.

For the interpretation different grades, grade 1, grade 2, grade 3 and grade 4 are assigned to the test result according to the criteria given in ASTM D 6572-12[5]. If the dispersive grade changed during the test the 1 h reading is normally used for overall test evaluation. If the grade changes from 2 to 3 or from 3 to 4 between 1 h and 6 h readings, use the 6 h reading.

For identifying dispersive characteristics the crumb test gives a positive indication. Figure-2 shows the four grades of reaction. Crumb tests were done with different concentrations of ammonium chloride and sodium hydroxide.

Table-2
Physical and chemical properties of pore fluids

Type of Liquid	Molecular Formula	Molecular Weight (g/mol)	Dielectric Constant at 20˚C	Surface Tension dyne/cm	Boiling Point ˚C	Colour
Sodium Hydroxide	NaOH	40.00	-	-	1660	White, waxy, opaque crystals
Ammonium chloride	NH_4Cl	53.491	4.3	-	520	White solid
Water	H_2O	18.02	80.2	72.75	100.0	colourless



No reaction **Slight reaction**

Moderate reaction **Strong reaction**

Figure-2
Grades of reaction from crumb test

Liquid limit test (IS 2720 part 5-1985): Liquid limit test was done according to IS specification[6]. Liquid limit test were done for both bentonite and metakaolin with sodium hydroxide and ammonium chloride as pore fluids with different concentrations.

Results and Discussion

Identification of Dispersive Soil: For the identification of dispersive soil crumb test was conducted.

The Crumb (ASTM D 6572-12): Crumb test were done for both bentonite and metakaolin[5]. Table-3 shows the results of crumb test. Figure-3 and Figure-4 shows the images of crumb test for metakaolin and bentonite after 6 hours. From results, metakaolin is found to be non dispersive which is of grade 1 and bentonite is found to be in grade 4 which shows strong reaction and found to be highly dispersive.

Effect of Various Pore Fluids on Liquid Limit of Clays: Effect Of Ammonium Chloride (NH_4Cl) On Liquid Limit: Different molarities of ammonium chloride solutions were prepared from respective salt varying from 0.1M to 0.4M. Then liquid limit test were performed at different percentages of solutions. Table-4 shows liquid limit variation with ammonium chloride solutions.

With the addition of different percentages of ammonium chloride a reduction in liquid limit was observed. For bentonite liquid limit reduction was about 54% and for metakaolin reduction was about 19% with 100% NH_4Cl addition. Compared to bentonite, reduction of liquid limit for metakaolin was not significant. Reduction on liquid limit value for bentonite occurs due to the decrease in volume of diffuse double layer. Reduction in liquid limit for metakaolin is due to the weakening of edge to face contact.

Table-3
Crumb Test Results

Soil	Crumb Test Results
Bentonite	Highly Dispersive (Grade 4)
Metakaolin	Non dispersive (Grade1)

Figure-3
Crumb test result for Metakaolin (after six hours)

Figure-4
Crumb test result for Bentonite (after six hours)

Effect of Sodium Hydroxide (NaOH) on Liquid Limit of Clays: Different normalities of sodium hydroxide solutions were prepared from respective salt varying from 0.1N to 0.4N. Then liquid limit test was performed at different percentages of solutions. Table-5 shows liquid limit variation with sodium hydroxide solutions. For bentonite liquid limit reduction was about 47% and for metakaolin reduction was about 48% with 100% NaOH addition.

Table-4
Variation of Liquid Limit with NH_4Cl

Concentration (M)	Liquid limit of Bentonite (%)	Liquid limit of Metakaolin (%)
	100%	**100%**
0	245	85
0.1	215.5	84
0.2	168	80.3
0.3	155	76
0.4	112.5	69

Table-5
Variation of Liquid Limit with NaOH

Concentration (N)	Liquid limit of Bentonite (%)	Liquid limit of Metakaolin (%)
	100%	**100%**
0	245	85
0.1	225	77
0.2	163.5	68
0.3	132.7	49.4
0.4	129.3	44.5

Conclusion

Presences of various pore fluids will change various properties of soil. In the present study investigations were done to study the differences in liquid limit for dispersive and non dispersive soils due to action of various pore fluids. Crumb tests were conducted to identify dispersive soil. From the series of liquid limit test conducted on bentonite and metakaolin, the following findings were made: i. Presence of pore fluids will lead to the disintegration of diffuse double layer and thus clay particles get thickened and liquid limit decreases, ii. For bentonite liquid limit reduction was about 54% and for metakaolin reduction was about 19% with 100% ammonium chloride solution (NH_4Cl) addition. iii. For bentonite liquid limit reduction was about 47% and for metakaolin reduction was about 48% with 100% sodium hydroxide solutions (NaOH) addition.

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